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SECTION II.—GENERAL METEOROLOGY.

PERIOD OF SAFE PLANT GROWTH IN MARYLAND AND DELAWARE.

By OLIVER L. FASSIG, Professor of Meteorology.

[Dated Weather Bureau, Baltimore, Md., Apr. 18, 1914.]

It is customary to establish the average period of safe plant growth for a locality by determining the average dates of the last killing frost in spring and the first killing frost in fall. When a temperature of 32°F. or below occurs without the occurrence of frost during a critical period after plant activity has begun in the spring, or in the early fall before the crops have all been gathered, the date of occurrence of the last and first temperature of 32°, respectively, is substituted in place of a killing frost in determining the average dates of the last and first frosts. The occurrence of frost does not generally coincide with the occurrence of a temperature of 32°, owing to the custom of exposing the thermometer in a shelter several feet above the ground. The difference between the temperature upon the ground and the temperature within the shelter, about 5 feet above the ground, may be as much as 10°, the amount of variation depending upon the topography and the weather conditions. As a rule [on cloudless nights] the temperature at the ground is distinctly lower during the night hours than the temperature in the shelter; this condition may be reversed, however. Since the intervals based on the last and first occurrence of frost, and those based on the last and first occurrence of a temperature of 32° F., are not of equal length, the usual method of calculating the frostless period from records made up by combining both kinds of observations (instrumental and phenological) is obviously open to criticism. The use of an occasional freezing temperature to complete a long record of observed frosts is not objectionable, but a frequent substitution should not be resorted to.

In order to learn the extent of the difference in the length of the frostless period, or the difference in the length of the period of safe plant growth as determined by means of the two methods described, two distinct series of observations were tabulated and compared for all stations in Maryland and Delaware having a record covering a period of 10 years or more. Fortunately we have in these States a large number of carefully made observations extending over periods varying from 10 to 43 years. The average length of these records is 20 years, confined mostly to the period 1890–1913. The tabulated results of a study of these observations show the following facts of observation and of calculation for each of fifty-two stations in Maryland and Delaware:

1. The elevation of the station above sea level.
2. The length of the period of temperature observations.
3. The average date of the last killing frost in spring.
4. The average date of the first killing frost in fall.
5. The average length of the intervening period.
6. The average date of the last temperature of 32° in spring.
7. The average date of the first temperature of 32° in fall.
8. The average length of the intervening period.
9. The difference in the length of the two intervening periods, based respectively on frost observations and on temperature observations.
10. The earliest and latest occurrence of the last temperature of 32° in spring.
11. The average departure from the normal date of the last spring temperature of 32°.
12. The earliest and latest occurrence of the first temperature of 32° in fall.
13. The average departure from the normal date of the first temperature of 32° in fall.
14. The longest period of safe plant growth, with year of occurrence.
15. The shortest period of safe plant growth, with year of occurrence.
16. The extreme variation in the period of safe plant growth.
17. The average departure, in days, from the normal length of the period.

The tabulated material has also been charted in order to show at a glance the geographical relations of the values determined. A comparison of the figures and charts showing the length of the two growing seasons suggests the advisability of adopting a uniform method of determining the period of safe plant growth, and appears to demonstrate the superiority of the method based upon the last and first occurrence of a fixed temperature, for example 32° F., over the usual method of observing and recording the dates of the last and first killing frosts in spring and fall, respectively.

Some of the reasons which may be advanced in favor of the method of determining the period from the temperature records are the following:

1. The temperature is observed and recorded regularly each day, and the record is therefore complete for the entire season.
2. Frost records are apt to be incomplete unless they occur at critical periods in plant growth. This failure to record frosts is particularly noticeable in records of spring frosts; stations having excellent fall records have often a very defective record of spring frosts. Frosts occurring after a long period of warm weather, as in summer or early fall, are likely to be more conspicuous events than the last of a series of many frosts occurring throughout the winter and early spring.
3. In recording frosts there is always a variable personal factor, opinions differing as to the extent and severity of the frost, resulting in the same frost being designated as "heavy" or "killing." In recording temperatures, on the other hand, this personal factor is practically eliminated.
4. There is a fairly fixed and uniform relation existing between the temperature in the shelter and the occurrence of a killing frost in any given locality, and this factor can be readily determined from a comparatively short series of observations.
5. For reasons stated above a reliable "frostless period" may be established for a given locality from a shorter series of observations by the use of a temperature record than by the use of a frost record.

The Maryland and Delaware records, covering an average period of 20 years at 50 stations, show that the frostless period based on the observations of a temperature of 32°F. is about 10 days longer than the period based on the occurrence of killing frosts. This relation holds good in general for stations in open, level places, but apparently does not hold for stations in the mountain districts, where the period based on the occurrence of frosts is longer than that determined from a record of freezing temperatures in a shelter 5 feet above the ground.

The longer "frostless period" in the mountains is explained by the fact that the last frost in spring and the first in fall occur late in the spring and early in the fall, at times when the ground is warmer than the air above it. This explanation is supported by the fact that the average temperature at the time of occurrence of killing frosts at the stations in question is found to have been between 28°F. and 30°F., while the average temperature at the time of occurrence of killing frosts at the level lowland stations is found to have been approximately 32° F.

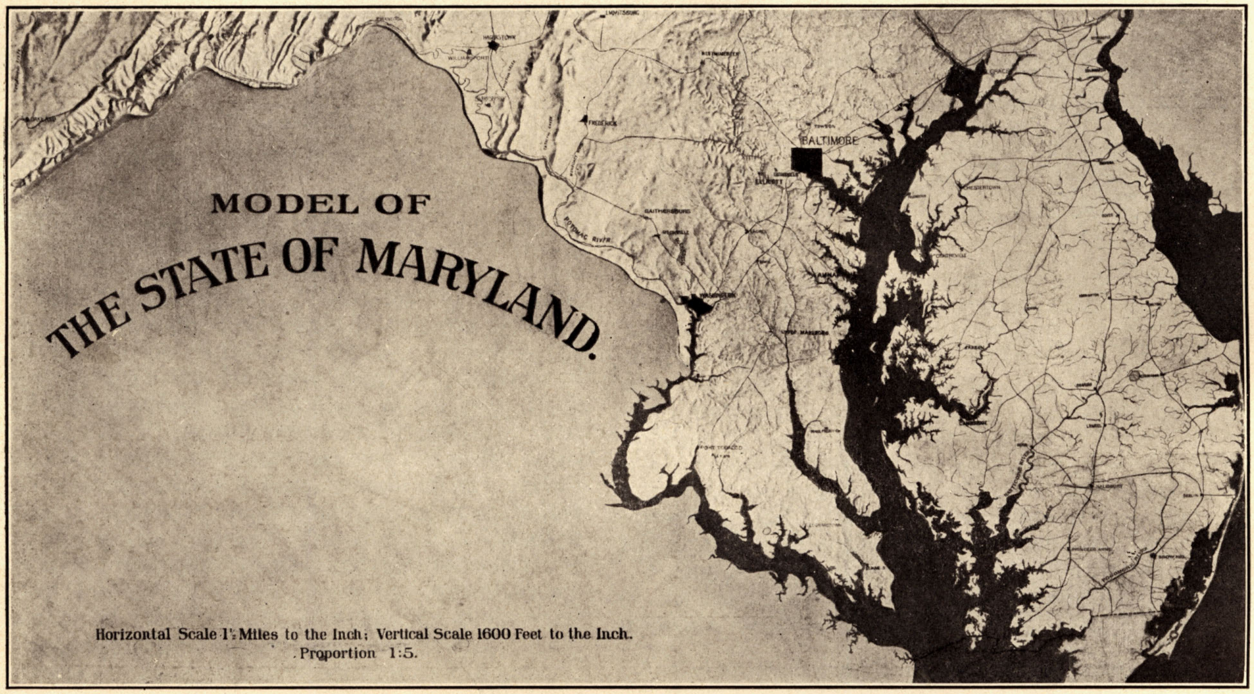

FIG. 1.—Relief map of the States of Maryland and Delaware. (Courtesy of Maryland Geological Survey.)

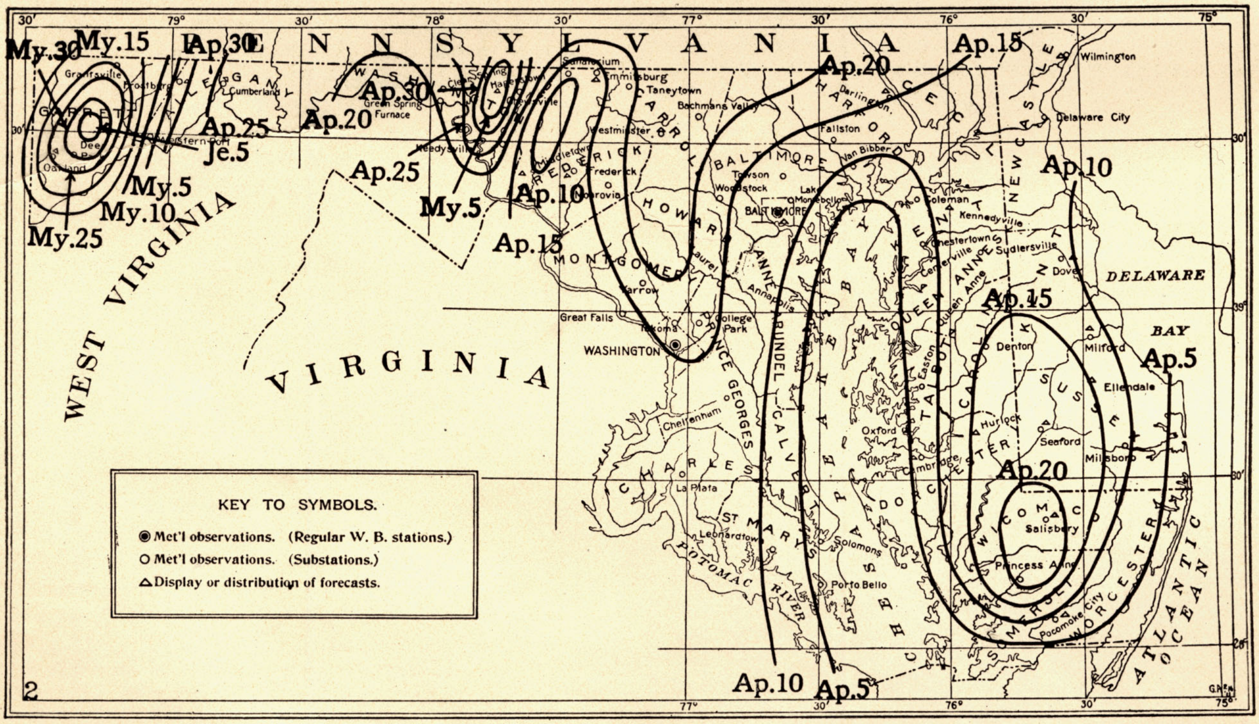

FIG. 2.—Average date of occurrence of the last temperature of 32° F. in spring in Maryland and Delaware.

Laurel is the one exception to the general rule that in the level lowlands the period based on a temperature of 32°F. is longer than the period based on frost observations, and the difference here is small, namely, two days. It is noteworthy that Laurel is the one station at which the thermometer shelter is 6 inches above the ground, while at all other stations the shelter is placed at an elevation of about 5 feet above the ground.

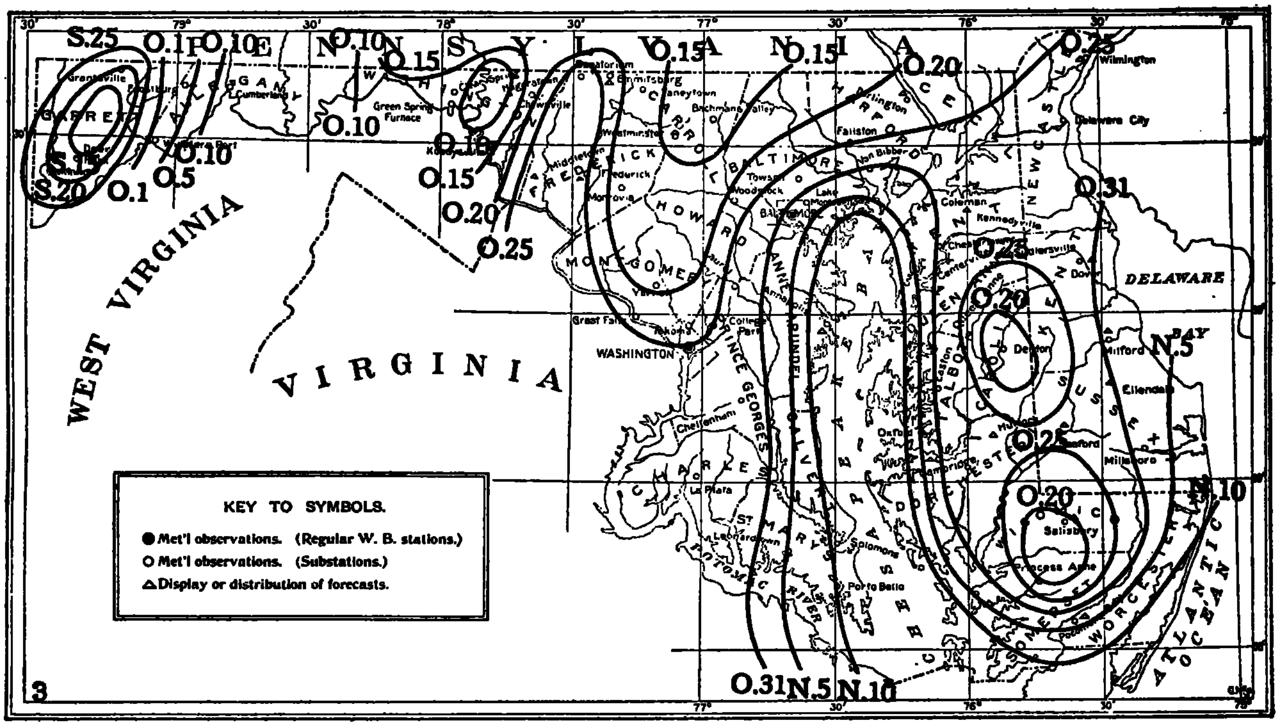

FIG. 3.—Average date of occurrence of the first temperature of 32° F. in fall in Maryland and Delaware.

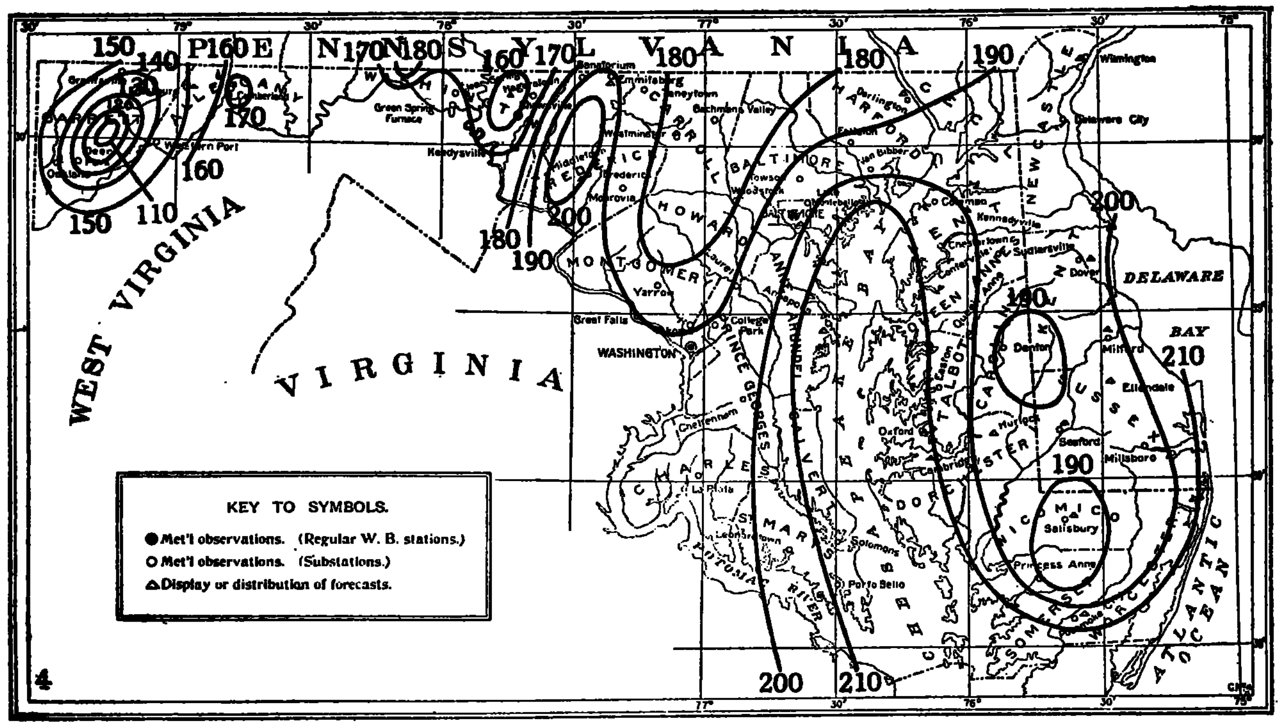

FIG. 4.—Average length of the period of safe plant growth. (Based on number of days between last spring and first fall temperature of 32° F.)

The necessity for charting these two systems of observations separately is apparent, and I believe that the method based on a record of the last temperature of 32° F. in spring and the first temperature of 32° F. in fall is the better method. The formation of frost depends not only upon the occurrence of a temperature of 32° F. or lower, but also upon the relative humidity of the air at the time and place of formation; the temperature may fall consid-

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erably below the freezing point for water without the occurrence of frost in a dry atmosphere. The injury to plants is probably as great in one case as in the other, yet the absence of frost may give the impression that no injury has resulted.

A comparison of the charted results of the two methods shows a similar configuration of the lines of equal frostless periods (figs. 4 and 8), and of lines showing the beginning and ending of the periods (figs. 2, 3, 6, and 7); but the charts based upon the temperature records (figs. 2, 3, and 4) show greater detail owing to the use of a greater number of stations and a greater average length of the periods of observation permitted by the temperature method.

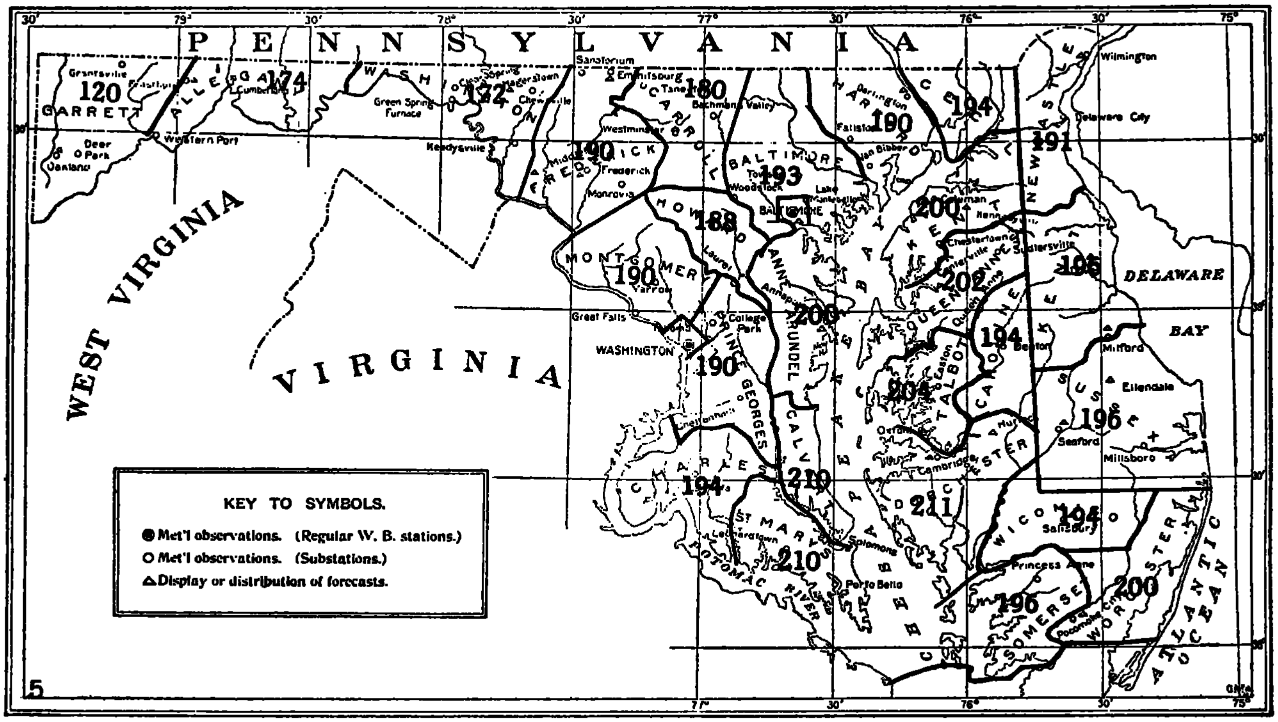

FIG. 5.—Average length in days of the period of safe plant growth, by counties. (Period between last spring and first fall temperature of 32° F.)

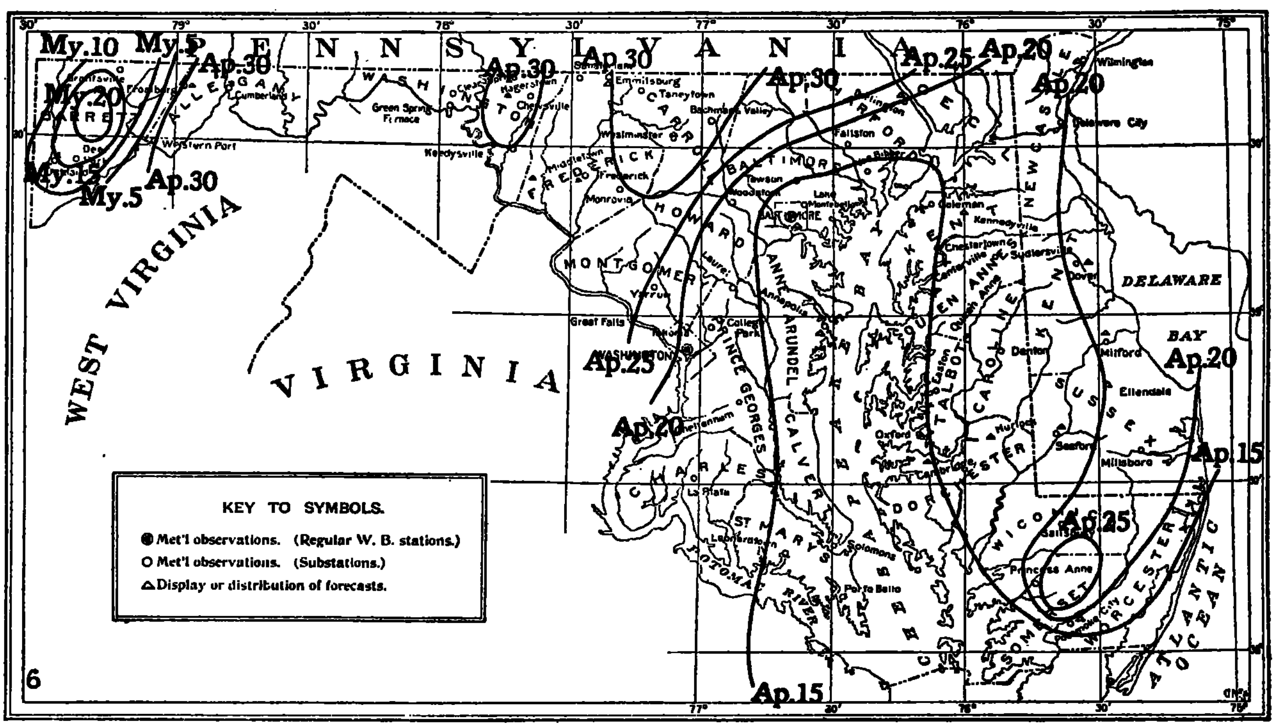

FIG. 6.—Average date of the last killing frost in spring.

Nearly all of the temperature observations used in the construction of the accompanying charts were made under similar methods of exposure of thermometers, viz, in like Baltimore and Washington where the thermometers are exposed upon the roofs of buildings at elevations of 100 feet or more above the ground.

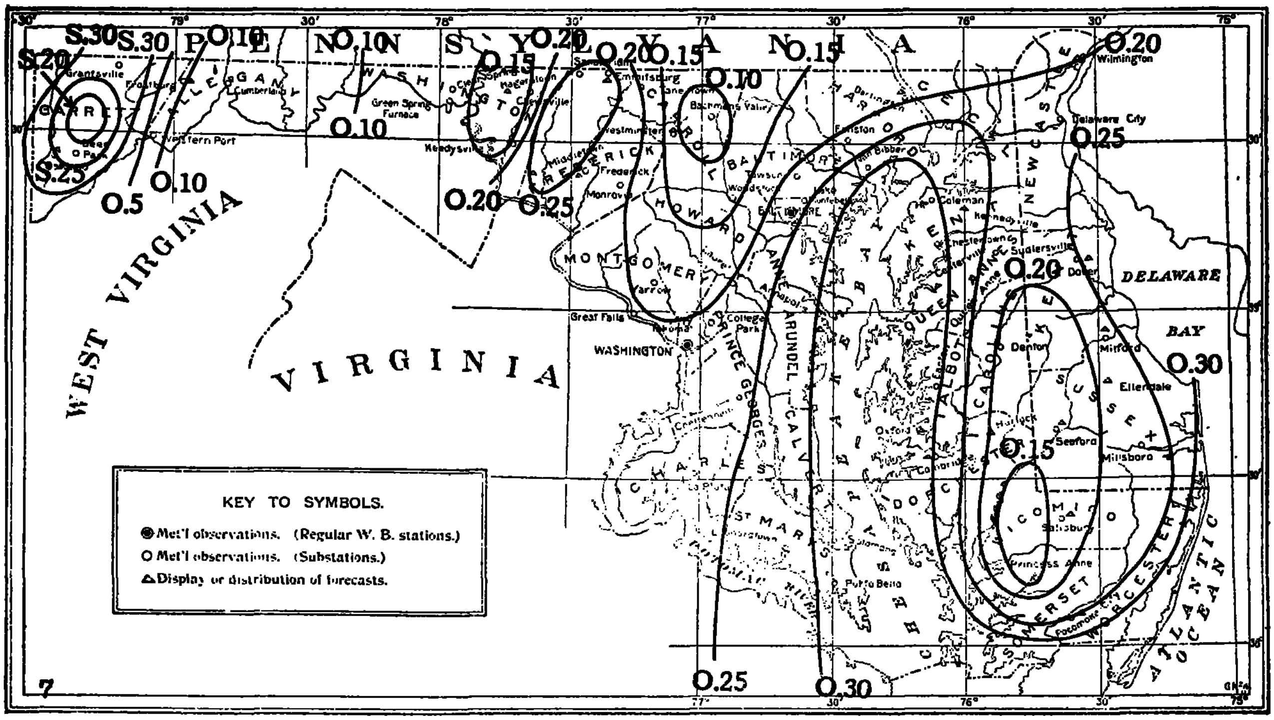

FIG. 7.—Average date of the first killing frost in fall.

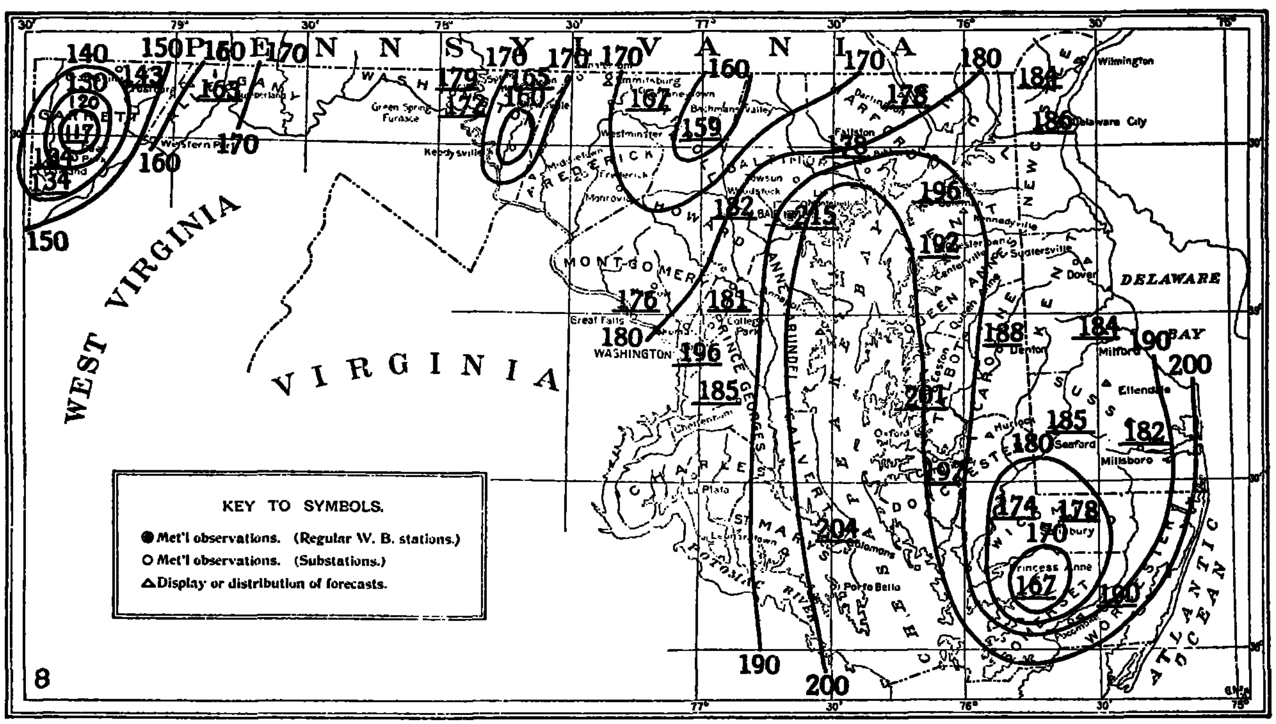

FIG. 8.—Average length, in days, of the frostless period. Local intervals are underscored.

standard Weather Bureau shelters about 5 feet above the ground in country districts or in open places in small towns. Proper allowance must be made for temperatures observed under conditions which differ widely from the usual methods of exposure, such as those of large cities

The charts show quantitatively what has long been recognized in a general way, viz, the great influence of Chesapeake Bay in lengthening the period of safe plant growth in Maryland. This fact is conspicuous in all the charts.

TABLE 1.—*The period of safe plant growth in Maryland and Delaware.*

	Stations.	Elevation.	Period.	Killing frost. Average date. Last in spring.	Killing frost. Average date. First in fall.	Killing frost. Interval.	Temperature of 32° F. Average date. Last in spring.	Temperature of 32° F. Average date. First in fall.	Temperature of 32° F. Interval.	Difference between frostless and temperature periods.	Spring. Earliest date.	Spring. Latest date.	Spring. Average departure.	Fall. Earliest date.	Fall. Latest date.	Fall. Average departure.	Period of safe plant growth (in days). Longest.	Year.	Shortest.	Year.	Extreme range.	Average departure from normal safe growing period.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Maryland.	*Feet.*	*Yrs.*			*Days*			*Days*	*Days*						*Days*	*Days*		*Days*		*Dys*	*Dys*
1	Annapolis	45	18	....	....	....	Apr. 12	Nov. 3	205	....	Mar. 29	May 5	±10	Oct. 1	Dec. 1	±10	241	1896	170	1906	71	±14
2	Bachmans Valley	860	17	May 2	Oct. 8	159	Apr. 24	Oct. 12	171	12	Apr. 4	May 16	10	Sept. 9	Oct. 30	8	197	1902	140	1904	57	13
3	Baltimore	115	43	Apr. 4	Nov. 5	215	Apr. 3	Nov. 12	223	9	Mar. 16	Apr. 22	7	Oct. 29	Dec. 6	8	278	1871	194	1904	84	12
4	Boetcherville	780	13	Apr. 26	Oct. 6	163	Apr. 23	Oct. 7	167	4	Mar. 30	May 21	11	Sept. 15	Nov. 9	10	212	1894	139	1905	73	15
5	Cambridge	25	16	Apr. 18	Nov. 1	197	Apr. 7	Nov. 7	214	17	Mar. 20	Apr. 20	6	Oct. 13	Nov. 29	9	254	1902	190	1907	64	15
6	Charlotte Hall	167	13	....	....	....	Apr. 14	Oct. 24	195	....	Mar. 30	Apr. 28	7	Oct. 1	Nov. 14	10	209	1896	172	1898	37	14
7	Cheltenham	230	14	Apr. 21	Oct. 23	185	Apr. 15	Oct. 24	192	7	Mar. 22	May 12	10	Oct. 11	Nov. 14	7	222	1910	153	1906	69	16
8	Chestertown	80	19	Apr. 16	Oct. 25	192	Apr. 12	Oct. 30	201	9	Mar. 19	May 1	8	Oct. 5	Nov. 14	7	225	1910	171	1907	54	11
9	Chewsville	530	16	Apr. 30	Oct. 12	165	May 6	Oct. 9	156	* 9	Apr. 5	May 29	12	Sept. 14	Nov. 1	11	202	1898	125	1905	77	18
10	Clear Spring	650	16	Apr. 23	Oct. 19	179	Apr. 15	Oct. 22	190	11	Mar. 20	May 12	10	Oct. 1	Nov. 3	8	218	1910	162	1907	56	16
11	Coleman	80	16	Apr. 14	Oct. 27	196	Apr. 10	Nov. 1	205	9	Mar. 29	Apr. 20	6	Oct. 20	Nov. 15	5	226	1906	191	1904	35	8
12	College Park	170	22	....	Oct. 9	....	Apr. 28	Oct. 12	167	....	Apr. 9	May 16	10	Sept. 22	Oct. 31	8	202	1898	131	1904	71	13
13	Cumberland	623	27	....	....	....	Apr. 12	Oct. 27	198	....	Mar. 22	Apr. 26	6	Oct. 10	Nov. 24	10	227	1886	172	1888	55	14
14	Darlington	300	22	Apr. 25	Oct. 20	178	Apr. 18	Oct. 23	188	10	Mar. 30	May 11	9	...do...	Nov. 6	6	210	1901	154	1906	56	10
15	Deer Park	2,457	19	May 25	Sept. 19	117	June 5	Sept. 15	103	*14	May 3	July 31	19	Aug. 22	Oct. 10	9	135	1906	48	1909	87	20
16	Denton	42	17	Apr. 14	Oct. 19	187	Apr. 16	Oct. 20	187	0	Mar. 30	May 12	....	Sept. 23	Nov. 6	10	216	1893	153	1904	63	14
17	Easton	35	21	Apr. 12	Oct. 30	201	Apr. 11	Oct. 29	201	0	Mar. 22	Apr. 28	7	Oct. 2	Nov. 19	9	223	1894	174	1899	49	12
18	Emmitsburg	720	33	....	Oct. 27	....	Apr. 11	Oct. 29	201	....	Mar. 25	May 10	8	Oct. 7	Nov. 16	9	232	1888	155	1906	77	14
19	Fallston	450	21	Apr. 21	Oct. 16	178	Apr. 15	Oct. 22	189	11	Mar. 19	May 12	10	Oct. 3	Nov. 14	8	224	1910	163	1907	61	12
20	Frederick	275	25	....	Oct. 22	....	Apr. 11	Oct. 24	196	....	Mar. 18	May 12	9	Sept. 23	Nov. 24	9	236	1890	154	1904	82	15
21	Frostburg	1,929	12	....	Oct. 10	....	Apr. 26	Oct. 10	167	....	Apr. 9	May 11	10	Sept. 23	Oct. 25	9	192	1898	135	1913	57	12
22	Grantsville	2,351	20	May 13	Oct. 1	141	May 15	Sept. 30	137	*4	Apr. 22	June 8	10	Sept. 14	Oct. 25	10	171	1911	95	1913	76	18
23	Great Falls	200	30	Apr. 28	Oct. 21	176	Apr. 16	Oct. 18	185	9	Mar. 23	May 12	11	Oct. 2	Nov. 7	8	222	1910	154	1906	68	15
24	Green Spring	450	19	Apr. 26	Oct. 15	172	Apr. 27	Oct. 14	170	*2	Apr. 9	May 21	11	Sept. 23	Oct. 31	8	196	1898	147	1907	49	12
25	Hancock	455	10	....	Oct. 11	....	Apr. 23	Oct. 3	163	....	Apr. 9	May 12	9	Sept. 15	Oct. 28	10	202	1898	143	1895	59	13
26	Jewell	165	14	....	Oct. 25	....	Apr. 9	Oct. 31	205	....	Mar. 20	Apr. 28	9	Oct. 10	Nov. 13	8	224	1902	183	1898	41	12
27	Keedysville	400	19	Apr. 25	Oct. 11	169	May 3	Oct. 16	166	7	Apr. 11	May 16	9	Oct. 3	Oct. 25	8	188	1912	154	1906	34	8
28	Laurel	150	19	Apr. 21	Oct. 19	181	Apr. 24	Oct. 20	179	*2	Apr. 9	May 12	8	Oct. 4	Nov. 15	7	201	1898	154	1906	47	9
29	McDonogh	500	28	....	....	....	Apr. 14	Oct. 27	196	....	Mar. 26	May 9	9	Sept. 23	Nov. 18	9	228	1881	155	1904	73	12
30	Mardela Springs	25	12	....	....	....	Apr. 12	Oct. 24	195	....	Mar. 29	May 4	7	Oct. 3	Nov. 7	10	222	1889	175	1899	47	12
31	New Market	630	25	....	Oct. 20	....	Apr. 15	Oct. 22	190	....	Mar. 16	May 12	10	Oct. 1	Nov. 13	9	227	1910	150	1907	77	14
32	Oakland	2,461	13	May 19	Sept. 27	131	May 21	Sept. 18	117	*14	May 3	June 11	9	Aug. 27	Oct. 10	10	144	1893	92	1913	52	12
33	Pocomoke City	37	20	Apr. 16	Oct. 23	190	Apr. 7	Nov. 6	211	23	Mar. 18	Apr. 28	9	Oct. 1	Dec. 8	11	227	1903	192	1906	35	9
34	Princess Anne	17	20	Apr. 30	Oct. 14	167	Apr. 21	Oct. 19	181	14	Apr. 9	May 12	9	Oct. 1	Nov. 2	8	199	1910	153	1896	46	11
35	Salisbury	23	10	Apr. 23	Oct. 16	176	Apr. 24	Oct. 20	179	12	Apr. 9	May 12	10	Oct. 12	Nov. 2	6	191	1912	154	1906	37	10
36	Sandy Spring	500	17	Apr. 18	Oct. 18	183	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
37	Sharpsburg	420	10	....	Oct. 4	....	Apr. 11	Oct. 17	180	....	Mar. 30	Apr. 22	6	Oct. 1	Nov. 9	11	212	1900	175	1895	37	13
38	Solomons	20	21	Apr. 13	Nov. 3	204	Apr. 3	Nov. 19	230	26	Mar. 16	Apr. 27	8	Nov. 5	Dec. 5	7	254	1902	203	1893	51	12
39	Sudlersville	65	16	....	Oct. 22	....	Apr. 13	Oct. 25	195	....	Apr. 3	Apr. 23	6	Oct. 7	Nov. 7	8	216	1903	170	1904	53	9
40	Sunnyside	2,440	11	May 11	Sept. 22	134	May 15	Sept. 14	122	*12	Apr. 18	June 9	16	Sept. 2	Sept. 25	7	152	1896	88	1902	64	17
41	Takoma	320	15	....	Oct. 24	....	Apr. 10	Oct. 25	198	....	Mar. 20	Apr. 21	7	Oct. 12	Nov. 9	7	223	1900	176	1905	47	11
42	Taneytown	490	14	Apr. 30	Oct. 14	167	Apr. 24	Oct. 13	172	5	Apr. 6	May 22	14	Oct. 2	Nov. 3	6	194	1898	140	1907	54	13
43	Van Bibber	100	16	....	....	....	Apr. 15	Oct. 27	195	....	Mar. 29	May 12	10	Oct. 17	Nov. 14	6	218	1900	163	1913	55	10
44	Western Port	1,000	19	....	....	....	Apr. 30	Oct. 11	164	....	Apr. 8	May 21	12	Sept. 20	Oct. 30	9	191	1912	132	1895	59	11
45	Woodstock	392	40	Apr. 15	Oct. 14	182	Apr. 15	Oct. 19	187	5	Mar. 22	May 11	8	Oct. 2	Nov. 4	9	222	1910	153	1882	69	14
	Delaware.																					
46	Delaware City	10	11	Apr. 20	Oct. 23	186	Apr. 18	Oct. 27	192	6	Mar. 22	May 11	9	Oct. 11	Nov. 9	7	221	1910	186	1908	35	14
47	Dover	40	20	....	Oct. 28	....	Apr. 9	Nov. 4	209	....	Mar. 20	Apr. 28	8	Oct. 14	Nov. 29	6	251	1876	183	1907	68	15
48	Milford	20	25	Apr. 25	Oct. 26	184	Apr. 12	Oct. 28	199	15	Mar. 16	May 3	8	Oct. 2	Nov. 18	9	228	1902	168	1874	60	12
49	Millsboro	20	21	Apr. 21	Oct. 20	182	Apr. 17	Oct. 24	190	8	Mar. 30	May 11	8	Oct. 4	Nov. 11	8	214	1893	154	1906	60	11
50	Newark	136	20	Apr. 15	Oct. 16	184	Apr. 15	Oct. 22	190	6	Mar. 18	May 12	9	Oct. 2	Nov. 16	9	226	1908	161	1907	65	13
51	Seaford	40	20	Apr. 18	Oct. 20	185	Apr. 13	Oct. 28	198	13	Mar. 18	May 12	7	Oct. 18	Nov. 13	8	236	1901	163	1913	73	12
	District of Columbia.																					
52	Washington	112	42	Apr. 9	Oct. 22	196	Apr. 8	Oct. 30	205	9	Mar. 18	Apr. 29	7	Oct. 10	Nov. 18	8	229	1886	169	1874	60	10

* Frostless period longer than temperature period. At all other stations the temperature period is longer than the frostless period.

The protecting influence of the mountains in the western part of Maryland (see fig. 1 for topography of the State) is also clearly shown in the greater length of the frostless period on the eastern, or leeward side, and in the contrast between conditions on the western and eastern sides of the Blue Ridge Mountains in Washington and Frederick Counties.

The period of safe plant growth along Chesapeake Bay in southern Maryland, is longer by nearly 100 days than the period in Garrett County in the mountains of western Maryland.

Taking the average for a long series of years, a temperature of 32° F. or below disappears in spring along the shores of Chesapeake Bay and along the Atlantic coast about April 5, to reappear in the fall about November 10 or 12, showing a period of safe plant growth of about 210 days. These figures apply, however, only to localities near the shore. The length of the period diminishes rather rapidly with increasing distance from the water's edge. This protecting influence of the Bay is strikingly brought out in figure 4, showing the variations in the length of the frostless period on what is known as the "Peninsula," including Delaware and the district in Maryland between the Atlantic Ocean and Chesapeake Bay. In the central portions of the Peninsula, farthest away from the Bay and the ocean, regions in which nocturnal radiation is more active than in the immediate vicinity of large bodies of water, freezing temperatures do not usually disappear in the spring until April 15 to 20, and reappear in the fall about October 20 to 25, de-

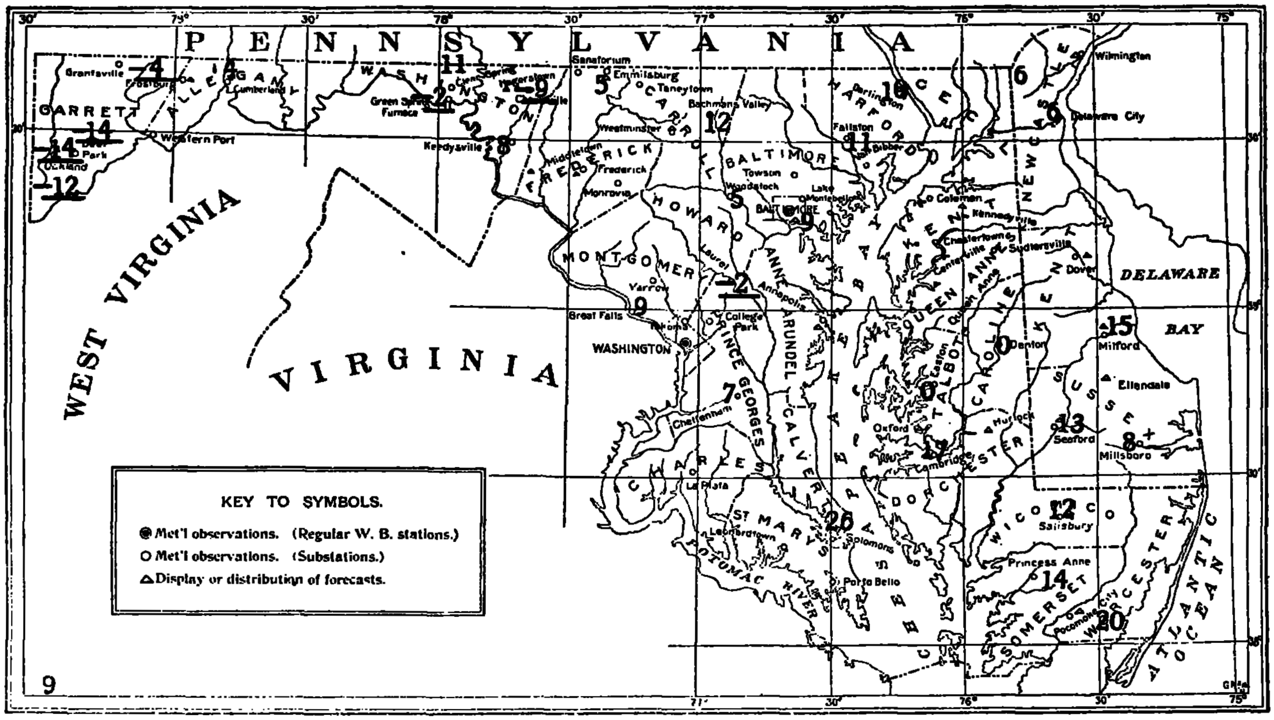

FIG. 9.—Difference in days between the periods of safe plant growth as based on frost data and on temperature data. Plain figures indicate temperature period greater than frost period. Underscored figures indicate frost period greater than temperature period.

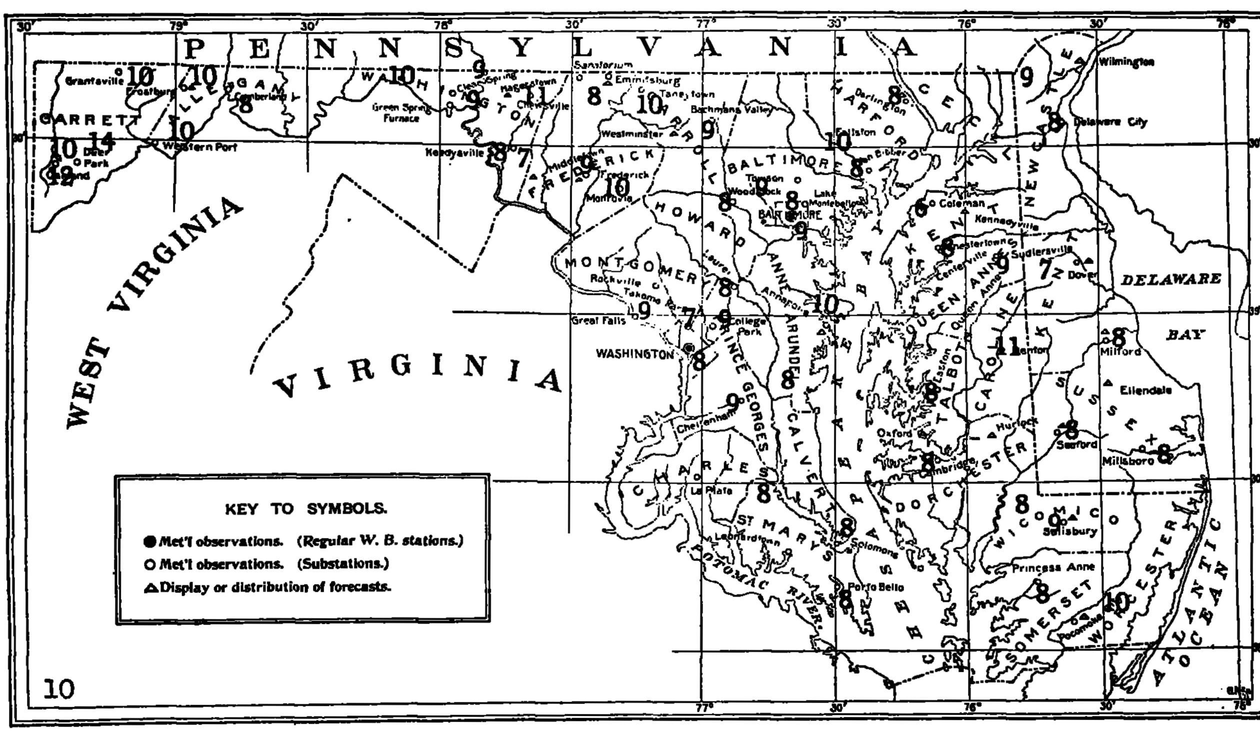

FIG. 10.—Average departure, in days, from the average dates of the last spring and first fall temperature of 32° F.

creasing the period of safe plant growth from 210 days near the shores to 190 days at distances only 20 to 25 miles inland, a difference of 20 days. Differences in soils are doubtless in part responsible for these variations.

In the mountain districts of the Blue Ridge (see fig. 1) we have a striking example of the protecting influence of a mountain range stretching across the path of the prevailing westerly winds. On the western or windward side of the Blue Ridge, in the lower levels of the Cumberland Valley, the frost period extends into the first week of May and reappears in the fall in the first decade of October, showing a period of safe plant growth of about 160 days. On the eastern or protected side of the Ridge the period is lengthened to 190 days, and even 200 days, the freezing temperatures disappearing about April 15 and reappearing in the third decade of October. In the mountain districts the variations in the length of the season are to some extent due to cold-air drainage during clear and calm nights and can not be altogether attributed to the protecting influence of the mountains against the cold westerly winds.

In the most western county of Maryland we find another factor entering into the length of the period of safe plant growth, namely, that of elevation, as shown by figure 1. The general level of Garrett County is not far from 2,500 feet above sea level, with peaks rising to 3,000 feet. Here we have a very decided shortening of the period, injurious frosts extending into the early days of June and appearing again about the middle of September, showing a period of safe plant growth of but little more than 100 days in the areas exposed to intense nocturnal radiation and to extensive air drainage.

THE PROGRESS AND PRESENT STATE OF RESEARCH ON THE EVAPORATION OF MOISTURE IN THE ATMOSPHERE.

[Communicated to the International Meteorological Congress at Chicago, Ill., August, 1893.]

By Prof. Dr. AUGUST WEILENMANN.

[Dated, Zurich, July, 1893. Revised by the author March 24, 1901.]

[Prof. August Weilenmann died at Zurich, November 10, 1906, at the age of 64. Besides his activities in his chosen field of astronomy, he ranked among the leading Swiss meteorologists of his time. Under the general direction of the astronomer Wolf, he was put in charge of the observational material collected by the meteorological réseau of Switzerland when that work was begun in 1863-64 under the care of the then newly established astronomical observatory of the Federal Polytechnikum. He continued in charge of this work, contributing many papers to the "Schweizerische meteorologische Beobachtungen," until 1872, when he was succeeded by Billwiller.

In 1873 Weilenmann withdrew from the astronomical observatory and devoted himself with brilliant success to teaching mathematics, physics, and meteorology in the higher cantonal schools. For 30 years he lectured on meteorology at the University and the Polytecnikum in Zurich. His extremely clear and inspiring lectures made all these subjects interesting and useful to a very wide circle of hearers.

The present paper, as noted above, was revised by its author and prepared for publication in 1901; publication has been delayed for the reasons stated in the REVIEW for February, 1914, p. 93.—C. A., jr.]

The evaporation of moisture was for a long time totally neglected in meteorology as a matter of observation, although it is one of the most important of the elements whose concurrence constitutes the weather. Kämtz in his Meteorology in 1831 gives only three pages to this phenomenon and mentions only the observations of Dalton in England and of some others made at various places in France and Holland. Schübler in his Meteorology of 1831 gives his own results at Tübingen. Schmid in his great treatise of 1860 knows no other observations than those already mentioned, by Kämtz and Schübler, and on page 600 he says: "The total result of these observations on evaporation simply leads to the conclusion that it is absolutely impossible to determine even approximately the quantity of moisture that passes from the surface of the earth into the atmosphere during a given time and at a given place." Although this conclusion may be true to a certain degree, and although the observations made under diverse conditions may not be absolutely comparable and may differ in total amount from the quantities that evaporate from the ocean or the open surface of the land, still the researches and experiments on this subject are of great importance and furnish a useful factor wherewith to characterize the climate of a given place. Moreover, the observations organized by Wild in Russia and by Hann in Austria-Hungary show that the results obtained with similar instruments similarly exposed are comparable. Therefore, in spite of the discouraging words of Schmid, the observations of the evaporation of moisture have not been abandoned, but rather have been greatly increased since 1860. The space conceded to this present report does not allow me to communicate all[1] that has been accomplished within the past 50 years (1843-1892), but it may be sufficient to give the most important results. I shall divide this paper into two portions: Theory and Instruments and observations.

THEORY.

The well-known physicist Dalton was among the first to endeavor to state the connection between evaporation and the elements on which it depends. He gives the following formula for the rate of evaporation:

$$\frac{dv}{dt}=\frac{A\ (S-s)}{b}$$

In this formula A is a constant, S the maximum aqueous vapor pressure for the temperature of the water surface, s the actual vapor pressure present in the air, b the atmospheric pressure.

This expression does not take into account the very appreciable influence of the motion of the air or the wind.

A. Weilenmann, of Zurich, has treated (1) the same problem. The principle on which this theory is based is mathematically the same as that of the wave motion of the molecules of fluids, assuming a constant duration for the vibrations in the same fluid. It also takes into consideration the atmospheric pressure, b, which diminishes the amplitude of the vibrations, and the motion of the air which favors the renewal of that which has become saturated with vapor. It further assumes that the air moving close to the surface of the water becomes completely saturated. By this theory we find the following expression for the depth, h, of the layer of water evaporated in the time z.

$$1)\quad h=\frac{\beta}{b}\int_0^z m_1 dz+\beta_1\int_0^z m_1 w dz$$

where β and β_1 are constants; b the atmospheric pressure; $m_1=G_1-g_1$, where G_1 is the weight of the vapor in a cubic meter of saturated air at the temperature, t_1, of the surface layer of evaporating water, and g_1 the weight of the vapor actually existing in a cubic meter of air before con-

[1] See "An annotated bibliography of evaporation," MONTHLY WEATHER REVIEW, June, 1908, to June, 1909. Also reprinted.—EDITOR.